THE CORONAL ATMOSPHERE OF THE SUN[*]

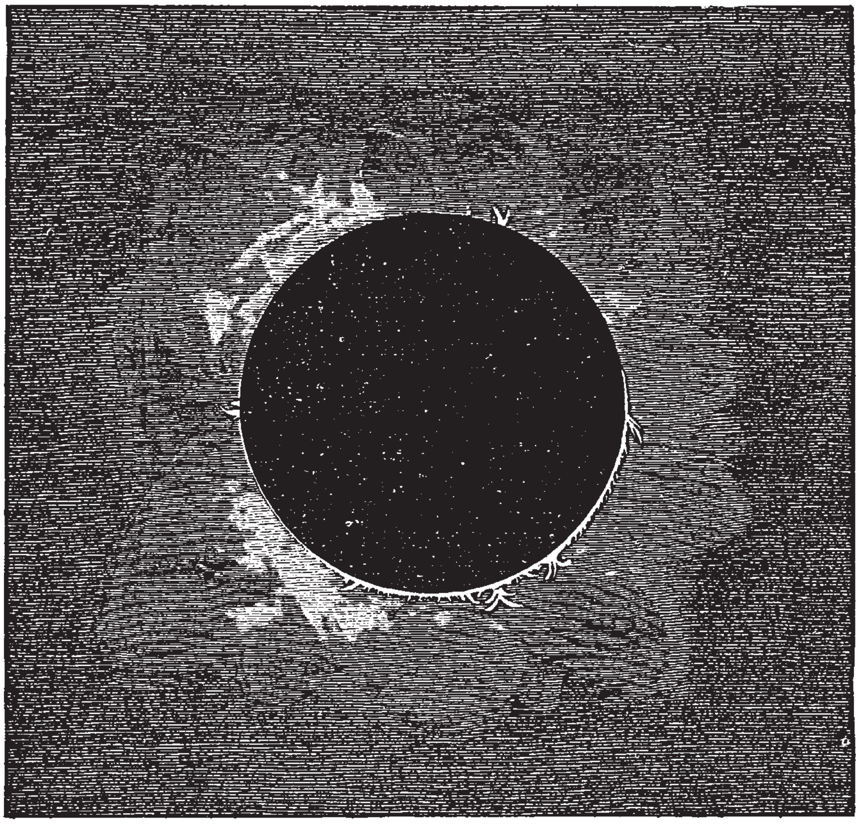
I.

I PROPOSE to bring before you rapidly the principal results obtained by me during the last total eclipse of the sun which I observed in Hindostan, at a point not very far distant from the place where I observed the great eclipse of 1868, which opened up such new horizons with regard to the constitution of the sun.

The last eclipse took place on December 12, 1871. The chief interest of the phenomenon is connected with the problem of the luminous corona which surrounds the sun during total eclipses. When that body is eclipsed by the interposition of the moon, you know that independently of those jets and luminous expansions which are known as protuberances, there is seen around the dark disc of our satellite a magnificent luminous phenomenon, resembling a glory or crown, which extends to 8′, 12′, 15′, and more from the lunar limb, and the frequent strange forms of which are variable at each eclipse. The observation of the eclipse which now occupies our attention, had for its object to definitely fix for us the nature of this singular phenomenon.

The corona is the luminous manifestation which is predominant during a total eclipse, and thus it must, at all times, attract the attention of observers. We possess, indeed, descriptions by Plantade, by Halley, by Louiville, and by others, which go back to the commencement of the 18th century; of course these observers did not indicate the cause of the phenomenon.

Arago and his school form a period in the history of the attempts which have been made to discover the nature of the corona. Our great physical astronomer applied the polariscopic methods to these investigations, but he as well as his successors were baffled. In the "Astronomie Populaire," published in 1856 (tome iii. p. 604), we read the following conclusion upon this subject: "I regret to say that the disagreement which has been found to exist between the observations made in different places by astronomers equally competent, on the luminous corona, in one and the same eclipse, has covered the question with such obscurities, that it is in the meantime impossible to arrive at any certain conclusion on the cause of the phenomenon."



By means of spectrum analysis the question has entered on a new phase. In 1868, while the nature of the protuberances was discovered, the spectrum of the corona was also obtained; it is true the observers found it continuous,[†] not an exact observation according to me, which retarded the solution of the question.

In the following year the Americans took up the matter.[*] They still found the continuous spectrum, but they established the existence of that celebrated green line (1474 in Kirchhoff's scale) which is the prevailing manifestation in the spectrum of the corona, and the meaning of which has yet to be discovered. We owe, moreover, to the Americans some very beautiful photographs of the protuberances, which show also the actinic power of the coronal light.

The eclipse of 1870 was marred by the bad weather, The few observations which could be made confirmed in general the observations of 1869.[†]

Thus, in 1871, we already possessed some very important data on the corona. Unfortunately these data were as yet incomplete, and above all inconsistent: for example, the continuity of the coronal spectrum, on the one hand, was inconsistent with the observations of polarisation of the corona, and on the other hand, led to the scarcely admissible conclusion of a corona formed of solid or liquid incandescent bodies. Thus the new eclipse, which presented a new opportunity of attacking this great question, the calculation of which, it was felt, must now be near, excited a general rivalry.

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[*] Translation of a paper read by M. Janssen at the Bordeaux meeting of the French Association for the Advancement of Science.

[†] Let us mention the observation of M. Rayet, who found luminous prolongation on the principal lines of the spectrum of a protuberance.

[*] The total eclipse of August 7, 1869, visible in N. America.

[†] We should mention, nevertheless, the beautiful observations of Mr. Young on the reversion of the lines at the base of the chromosphere.

England took the most considerable share in these observations. The [British Association, the] Royal Society, the Royal Astronomical Society, the Indian Government, worked harmoniously together. Among the noted men of science sent out, we shall mention specially Mr. Norman Lockyer, Colonel Tennant, Lieut. Herschel, Mr. Pogson, Capt. Fyers, &c. Italy was represented by M. Respighi, who was destined to make, on this occasion, some very beautiful observations; Holland by M. Oudemans, &c. At the request of the Academy and the Bureau des Longitudes, I was appointed by the French Government to represent France. It was a glorious charge for me, but at the same time a heavy one, which made me regret that circumstances did not permit of my having any French rivals.

The voyage being decided, it remained for me to settle the plan of my observations, the plan on which to set about to choose instruments, and to choose the place of observation. These points were of prime importance.

With regard to the plan of investigation, I knew very well that, coming after so many able men, I could not hope to solve the problem by simply adding to the numerous observations already made, a few similar observations. It was necessary to study the collection of known facts, to fix the obscure or contradictory points, and to secure a number of rapid observations (the totality would last only about two minutes in India) which should enable us to correct what was inaccurate, to complete what was insufficient, and to form, along with previous observations, a collection of data from which to deduce the true nature of the phenomenon. For example, I had no doubt, in spite of contrary observations, that the spectrum of the corona was not really discontinuous. I was persuaded that it must present, as a dominant characteristic, that of a spectrum of gas, and I found an explanation of the contrary appearances recorded in the feebleness of the light of the corona which did not admit spectra to be obtained, sufficiently luminous for discerning their true constitution. Thus, my intention was to bring my efforts to bear upon this chief point, to some extent the knot of the problem. The point was to obtain a spectrum much more luminous than those of my predecessors. For this purpose I constructed a special telescope having a mirror 37 centimetres in diameter, and a focus of $1^{m}{\cdot}43$, which gave spectra about 16 times more luminous than those of an ordinary astronomical telescope.

I attached also great importance to seeing the corona at the same time as I analysed its light. A special arrangement of the finder enabled me to attain this end.

Finally, a polarising telescope placed upon the large telescope enabled me to join the polariscopic indications to the other data, and to judge of their agreement. Such were my instrumental arrangements.

The choice of a station was of no less importance. At the point at which we had arrived, our investigations bore upon phenomena so delicate that a sky was required of absolute purity, if I may be permitted the expression. Let us say a few words as to where I sought to realise this second condition.

The eclipse was to be total in the south of Hindostan, at Ceylon, Java, and Australia. Australia was too far away. Java is, in December, subject to the rainy monsoon. There yet remained India and Ceylon, which represented for the line of totality a very considerable exentt, and offered a very great variety of stations from which to choose. To make this choice, I resolved not to trust to the general indications which we possess in Europe as to the climate of India, but to set out early, to visit all the stations, and to decide only after visiting the places, and collecting information on the spot.

I was at Ceylon by the beginning of November, nearly six weeks before the time of the eclipse, which would take place on December 12. On this island I was greatly assisted by the families Laggard and Ferguson, to whom I here beg to express my thanks. The information gathered in the north of the island, where the phenomenon would take place, was not so satisfactory as I desired, and it was agreed to seek for better fortune on the coast of Malabar. I then left Ceylon for Malabar, doubling Cape Comorin. On my way I made some magnetic determinations, and I had the good fortune to find that the magnetic equator, for the dip, passes quite close to Cochin. It was at Telecherry, an English post situated near the line of totality and the French colony of Mahé, that we disembarked. I was received by M. Baudry, a French merchant, who gave me a most gracious welcome and the most active assistance. Mahé was very valuable to me; our governor, M. Liotant, procured for me interpreters who spoke French and the dialects of the districts I was to traverse.

I had, meantime, to choose between the coast proper, the plain, and the stations of the Ghauts and the Neilgherries. As the eclipse was drawing near I could not think of sojourning at each station to make a lengthened investigation. I decided to utilise the telegraph and the railway * for making a simultaneous inquiry as to these stations. M. Baudry, whom I had instructed in observations to make every morning at the hour of the eclipse on the purity of the atmosphere at the coast, sent me these every day by telegraph. I had a similar station on the plain. The baggage had been taken to Coimbatoor, at the centre of the railway, ready to be conveyed speedily to the station selected. I myself visited the Neilgherries, and to gain time, I surveyed these mountains by utilising the night. The mass of information thus collected indicated the great superiority of the Neilgherries. A very careful investigation of this massive mountain-range induced me to locate my station in the north-west, where I had in fact much finer weather than in Dodabetta, one of the highest peaks, where Colonel Tennant and Lieutenant Herschel were afterwards established.

It was upon a mountain near Shoolor, an Indian village, lat. 11° 27′ 8″ N., long. 74° 22′ 5″ E. of Paris, that I fixed my observatory. The instruments were forwarded from Coimbatoor (at the foot of the Neilgherries) to Ootamacund in ox waggons. From Ootamacund to Shoolor the country consisted only of mountain and forest, without carriage roads, and the cases had to be carried on men's shoulders, the many difficulties attending which were happily overcome. Three days before the eclipse the observatory was erected, the instrument in place and ready for observation.

The observation at Shoolor was favoured by a sky of wonderful purity. As I have already indicated, my plan was to examine the corona from the triple point of view of its figure, its spectrum, and its phenomena of polarisation.

I first examined the corona in the telescope; the phenomenon was seen in all its splendour. The general form was that of a curvilinear square (*carré curviligne*), of which the outlines were irregular, but clearly defined. At its greatest height, the corona extended to about 14′ or 16′ from the lunar limb, and only to about half that distance at its narrowest parts. No diagonal was in the direction of the solar equator. All around the limb of the moon were seen trains of light which united towards the highest parts of the corona, and which gave to the entire phenomenon the appearance of a luminous and gigantic dahlia, the centre of which was occupied by the black disc of the moon.

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* There is a railway from Madras to the Malabar coast. I found it almost follow the direction of the line of totality.

The corona did not present any essential differences of structure at the point of contact and the opposite point. The motion of the moon did not appear to produce any change in the structure. These facts completely convinced me that the corona is a real object, situated beyond the moon, the gradual motion of which body reveals its various parts. Having finished this investigation, I turned my attention to the luminous elements of the phenomenon. My view being yet as distinct as ever, I commenced by examining the spectrum of the highest and least luminous parts of the corona. I placed the slit of the spectroscope at a point two-thirds of a radius from the moon's limb (*environ du bord lunaire*). The spectrum was seen much more vividly than I expected at that distance, a result evidently due to the luminous powers of the telescope and to the whole of the arrangements adopted. This spectrum was not continuous. I recognised at once the hydrogen lines and the green ray (1474).[*]

This is one point of the highest importance; I removed the slit, remaining always in the high regions of the corona; the spectra always presented the same constitution.

Starting from one of these positions, I descended little by little towards the chromosphere, examining very carefully the changes which might be produced. In proportion as I approached the moon, the spectra became more distinct and appeared richer, but they remained similar to the above in general constitution. In the middle heights of the corona, from 3′ to 6′ of arc, the dark line D was seen, as well as some obscure lines in the green; but these are at the limit of visibility. This observation proves the presence in the corona of reflected solar light, but it is seen that this light is drowned in an abundant extraneous (*étrangère*) luminous emission.

I then set myself to a very important observation, which I expected would give me the spectral relations between the corona and the protuberances. The slit was adjusted so as to take in a portion of the moon, a protuberance, and all the height of the corona. The spectrum of the moon was excessively pale; it appears due principally to atmospheric illumination, and gives a valuable idea of the feeble part which our atmosphere can play in the phenomenon of the corona.

The protuberance gave a very rich spectrum and one of great intensity; I had not time to make a detailed examination. The main point here is the establishment of the fact of the prolongation of the principal rays of the protuberance through all the height of the corona, which clearly demonstrates the existence of hydrogen in the latter.

The green line (1474), so vivid in the spectrum of the corona, appeared interrupted in the spectrum of the protuberance—a very remarkable result. I then gave a few moments to establish satisfactorily the exact correspondence of the lines of the corona with the principal lines of hydrogen in the protuberances.

There remained to me then only a few seconds for polariscopic observation.[†] The corona presented the characteristics of radial polarisation, and, it ought to be remarked, the maximum of effect is not observed at the lunar limb, but at some minutes from the edge.[‡]

I had scarcely finished this rapid investigation when the sun reappeared.

JANSSEN

(*To be continued.*)

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[*] My spectroscope was fitted with a very exact scale; but it will be seen how I afterwards made use of the lines of a protuberance as a scale.

[†] To study polarisation, I have an excellent telescope excellently constructed of biquartz, by M. Prazmowski. This polariscope, placed upon and adjusted to the telescope, can be consulted in an instant.

[‡] M. Prazmowski has noted this fact in his excellent polariscopic observations of the eclipse of July 17, 1860.

NOTES

THE subject of the Transit of Venus in 1874 was for the first time officially brought before the notice of the Board of Visitors at the recent Visitation of the Royal Observatory. After a careful exposition of the matter by the Astronomer Royal, and a consideration thereof by the Visitors, it was proposed and seconded by the Astronomical Professors of Cambridge and Oxford, that the Government be requested to provide the means of organising some parties of observers in the Southern Ocean, in the hope that they may find some additional localities for observing the whole duration of the Transit of Venus. In other language, they recommend strongly a sort of *roving* expedition. The meteorological and climatic difficulties both North and South are extremely great: the practical difficulties in the South are very peculiarly so; in despite of the latter, the Board of Visitors were unanimous in their advice to try what best can be done in the sub-antarctic regions. The Astronomer Royal expressed his perfect acquiescence in the proposal of the Visitors; the final decision will rest with the Admiralty and the Government. In coming to this decision, it is proper to add that the Board was in no degree either influenced or assisted by certain discussions which have taken place upon the subject out of doors; their decision would have been just the same whether these discussions had or had not taken place; and the Board came to their conclusion under a full knowledge of the very peculiar climatic and navigational difficulties which seem to attend on the roving expedition which they recommend. It is, in fact, only a realisation of an old proposal by the Astronomer Royal himself, which seems to have been set aside on account of the many serious practical difficulties attending it. The Astronomer Royal also proposed to organise some additional stations dependent on Honolulu.

MESSRS. SAMPSON LOW AND MARSTON are about to publish a volume on the subject of Arctic Exploration, by Mr. Clements Markham, entitled the "Threshold of the Unknown Region." It is intended to give a full account of all that is known of the line which, at present, separates the known from the unknown; to explain the best route by which the unexplored region may be examined; and to enumerate the important scientific results to be derived from Arctic exploration.

NATURALISTS will be glad to hear that the long-talked-of new buildings for the National Museum of Natural History, at South Kensington, have been actually commenced, and that the contractors, Messrs. Baker, have arranged to complete them within three years.

MR. F. T. WARNER, of Winchester, who for some time has been collecting materials for a Flora of Hampshire, has kindly offered the use of his collections and materials to Mr. Frederick Townsend with the proposal that he should complete the Flora. Mr. Townsend has accepted the offer, and as much work remains to be done, he invites the assistance of other botanists in furnishing him with lists of plants or in forming these during the present season. The value of lists will be greatly increased if accompanied by specimens, and in all cases exact localities and dates should be given. It is proposed to divide the country into river-basin districts. Letters should be addressed to Shedfield Lodge, Fareham, but parcels to Botley Station, London and South Western Railway. Mr. Townsend will gladly pay postage or carriage of parcels.

PROFESSOR ROLLESTON, of Oxford, is appointed to deliver the Harveian Oration at the Royal College of Physicians on June 25, at five o'clock.

IT is rumoured that Prof. Tyndall is to receive the honorary degree of D.C.L. from the University of Oxford during the ensuing Commemoration.